EVALUATION OF EFFECTIVENESS PARAMETERS ON GAS DEHYDRATION PLANT

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ABSTRACT

Natural gas in either from natural production or storage reservoirs contain water, which condensed and form solid gas hydrates that can cause trouble to the pipeline, increases the operating pressure and potential damage to the equipment. Thus dehydration of natural gas is important to ensure smooth operation of gas transmission line. This study focused on the dehydration by the absorption of liquid desiccant. The purpose of this study was to evaluate the effectiveness parameters used in Triethylene Glycol unit. Water need to be removed from the Natural Gas to meet a water dew point requirement of sale gas contract specification range from 32.8 to 117 kg/ 10^6 standard m^3. The evaluation of effectiveness parameters on gas dehydration plant used Aspen HYSYS. Peng-Robinson Equation of State has been chosen because the process involved hydrocarbon and water. The simulation was carried out to identify the effect of the parameter of column operating pressure, gas flow rate, inlet gas temperature and number of theoretical stages of the absorber. The optimum conditions of gas dehydration was at 7000 kPa with 100 mmscfd gas flow rate at 30 ^{o}C and 8 column theoretical stages.

PENILAIAN KEBERKESANAN PARAMETER PADA LOJI DEHIDRASI GAS

ABSTRAK

Gas asli sama ada daripada penghasilan semula jadi atau dari kolam simpanan, mengandungi air yang terkondensasi dan membentuk hidrat gas yang boleh mendatangkan masalah di dalam paip, meningkatkan kadar tekanan dan berpotensi untuk memusnahkan peralatan. Oleh itu proses penghidratan adalah penting untuk melancarkan operasi penghantaran gas. Kajian ini memfokuskan pada penghidratan secara penyerapan menggunakan cecair pengering. Tujuan kajian ini dijalankan adalah untuk mengenal pasti parameter yang efektif pada unit Triethylene Glycol. Kandungan air yang disingkirkan dari gas asli harus menepati keperluan tahap minimum kandungan air dalam gas yang telah ditetapkan oleh spesifikasi kontrak jualan gas iaitu dari 32.8 to 117 kg/ 10^6 m^3 . Penilaian keberkesanan parameter pada pelan penghidratan gas dilaksanakan menggunakan Aspen HYSYS . Persamaan Peng-Robinson digunakan selari dengan proses yang melibatkan hidrokarbon dan gas. Proses simulasi dijalankan untuk mengenal pasti kesan parameter iaitu kadar operasi tekanan di dalam kolum, kadar aliran gas, suhu gas, dan bilangan dulang kolum. Keadaan penghidratan gas yang optimum berlaku pada 7000 kPa, 100 mmscfd, 30 ^oC and 8 dulang kolum.

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LIST OF SYMBOLS

P	Pressure
V	Molar Volume
T	Temperature
R	Universal Gas Constant (8.314 $J.K^{-1}.Mol^{-1}$)
T_c	Critical Temperature
P_c	Critical Pressure
A	Alpha Function of Reduced Temperature

LIST OF ABBREVATIONS

TEG	Triethylene Glycol
PFD	Process Flow Diagram
BTEX	Benzene, toluene, ethylbenzene, xylenes
VOC	Volatile organic compound

CHAPTER 1

INTRODUCTION

1.0 Research Background

Natural gas is an environmentally friendly clean fuel and very safe source of energy. The lowest of carbon dioxide emissions makes this superior environmentally qualities over crude oil and coal. This can helps to reduce problems of acid rain, ozone layer depletion, or greenhouse effect.

Over thousands years ago, the uses of natural gas is specific for ignition only. In Persia, Greece, or India, they used the eternal flame for their religion's ritual until in 900 BC, the ancient Chinese were the first discovered and use natural gas. By the end of 1970s Japan was the world's largest importer of natural gas. Natural gas has been used mostly in North America, Europe, and Asia Pacific. North America has been largest self-sufficient with Canada as their exporter. In Saudi Arabia, natural gas reserves were estimated at 5.8 trillion m^3 in January 1999. Most known reserves are in the form of associated gas.

Nowadays, there are approximately 130 Underground Gas Storages (UGSs) inside the European Union. Their total maximum technical storage capacity is around 95 BCM. According to the largest update, over 70 BCM of additional storage capacity will come on stream in Europe till 2020.

There are two basic reasons why storing natural gas is an interesting idea. First it can decrease the dependency on supply. Second it can exploit the maximum capacity at distribution level. Natural gas is used as a fuel and raw material in manufacturing. It is used in home furnaces, water heating, and cooking stove.

Natural gas is a gaseous fossil fuel that are essentially the degradation of plants and animals and microorganism that lived millions years ago. Two main mechanisms are responsible for this degradation arebiosenic and thermosenic. Biosenic that is almost contained methane, formed at shallow depths and low temperature by anaerobic bacteria decomposition of sedimentary organic matter into organic matter. In contrast, thermosenic that formed at the deeper depths by the thermal cracking of sedimentary organic matter into hydrocarbon liquid and gas and thermal cracking of oil at high temperature into gas and pyrobitumen. Normally thermosenic consist ethane, propane, butane and other heavier hydrocarbons.

Natural gas produced from geological formations comes in a wide array of compositions. The varieties of gas compositions can be broadly categorized into three distinct groups: (1) non-associated gas, (2) associated gas and (3) continuous. Non-associated gas, sometimes called 'gas well gas' is produced from geological formations. It is typically do not contain much amount of methane but also can contain carbon dioxide and hydrogen sulphide. Associated gas is the gas that associated with crude oil that produced during crude oil production.

1.1 Problem Statement

Natural gas that comes from oil wells consist primarily methane is not totally pure but there are contaminants or mixture gas that typically contained water vapor, carbon dioxide, hydrogen sulphide, helium, nitrogen, and others. To get higher impurities of the gas, there are several process need to be done. The water contained in the gas can result in gradual plugging of the pipeline by the hydrates formation and also corrosion. These problems will affect the efficiency of gas transmissions and distributions.

1.2 Objectives

1.2.1 To evaluate the effectiveness parameters such as absorber operating pressure, number of theoretical stages, gas flow and inlet gas temperature on Natural Gas Dehydration Plant

1.2.2 To optimize the plant parameters of Triethylene Glycol (TEG) dehydration unit by using ASPEN HYSYS.

1.3 Scope of Research Work

The scope of the study was to study the optimum parameters of Triethylene Glycol, which were number of theoretical stages, pressure, gas flow rate and inlet gas temperature. Optimization of parameters will be made based on the performance of drying agent which is Triethylene Glycol. Absorption dehydration involves the use of the Triethylene Glycol to remove water vapor from gas.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Gas Composition

Natural gas that originated from underground comes from the decaying plants and animal that suspended a million years ago (Rebecca et. al., 1999). Natural gas is primarily in methane and along with heavier, more complex hydrocarbons such as ethane, propane, and butane (Mohan, 2008). Often, natural gas also contain impurities such as CO_2 (acid gas), hydrogen sulphide (sour gas), and water as well as nitrogen, helium, and other traces gases. All these contaminants must be removed to maintain the quality of gas before it is being sold.

In natural gas, the most common undesirable contaminant impurity is water that is either in a form of liquid or/and vapor. The amount of water content in the natural gas is varied depend on the pressure and temperature of the gas. The water content in the gas should be removed to the level of the allowable water content in the natural gas, 7 lb/MMscf at 4 Mpa (Michal, 2011).

Determination of water content in natural gas is important in evaluating and/or designing the gas dehydration system. Mcketta and Wehe chart (GPSA, 2004) provides the standard for water content determination (Saied et. al., 2006). This chart can be used to predict the saturated water content of sweet, pipeline quality natural gas. An appropriate method has been introduced by Wichert and Wichert that provides good estimations of the equilibrium water vapor content of natural gas.

Table 2.1 Component of natural gas

Components	Typical Analysis (mol %)	Range (mole%)
Methane	94.9	87.0 - 96.0
Ethane	2.5	1.8 - 5.1
Propane	0.2	0.1 - 1.5
i-Butane	0.03	0.01 - 0.3
n-Butane	0.03	0.01 - 0.3
i-Pentane	0.01	Trace - 0.14
n-Pentane	0.01	Trace - 0.04
Hexanes	0.01	Trace - 0.06
Nitrogen	1.6	1.3 - 5.6
Carbon Dioxide	0.7	0.1 - 1.0
Hydrogen Sulphate	1.0	0.1 - 5.0
Oxygen	0.02	0.01 - 0.1

A reasonable detailed summary of the water vapor problem in natural gas and various means which has been proposed for removing water vapor from natural gas is disclosed in (Athur et. al,. 1997).

Natural Gas in the right condition can combine with liquid or free water to form solid-ice like crystal called hydrates (Kasiri, 2004). Hydrates can block pipeline, valves, and other process equipment. Moreover, that water contaminant can increase the corrosivity especially when the acid gasses are present. In order to remove the water content, gas dehydration is the most prominent unit operations in natural gas industry.

In this operations, natural gas need to meet a sale gas contract and specification for water content in range from 32.8 to 117 kg/10^6 stdm^3(Gandhidasan et. al., 2000) .The water content of NG at saturation is dependent on temperature and pressure. With increasing pressure of the gas the water content decreases, and with increasing temperature the water content in the gas increases. This is well presented in Figure No. 20-3, Chapter 20, in the GPSA Data Book, 11th Edition. The water content of the gas can be calculated using the equation 1.1.

$$W_{water} = 593335 \exp(0.05486\, t_G)\ P_G^{-0.81462} \tag{2.1}$$

Where w_{water} is in kilograms of water per 10^6ms^{3}of NG, t_G is temperature of NG in °C, and P_G is pressure of NG in MPa.

2.2 Dehydration

Dehydration of natural gas is the removal of water content that associated with water in vapor form which is accomplished by lowering the dewpoint of the gas at which water vapor will condense from the gas (Gandhidasan et. al., 2000). Removing water content may maintain the efficiency of gas transmission and all at once save the maintenance cost of pipeline.

There are three different techniques employed for dehydrating natural gas which are absorption by liquid desiccants, adsorption by solid desiccant, and direct cooling (Gandhidasan et. al., 2000). Two of more prominent methods that are current use in industry are absorption and adsorption (Dan, 2009).Several other dehydration technologies are membranes, vortex tube, and supersonic process are used less commonly.

2.3 Dehydration by Adsorption

Solid desiccant dehydration systems basically work on the principle of adsorption (Saied et. al., 2006). Adsorption is purely a surface phenomenon which is, degree of adsorption is a function of operating temperature and pressure. Adsorption increase with pressure increased and decreased with the temperature increased (Gandhidasan et. al., 2000) .In this method H_2O usually adsorbed by a molecular sieves, silica gel or alumina (Michal, 2011).

Table 2.2 Properties of solid desiccant

Property	Silica gel	Alumina	Molecular sieves
Surface area	750-830	210	650-800
Pore volume	0.4-0.45	0.21	0.27
Pore diameter	21-23	26	11.4
Bulk density	721	801-881	689-721
Specific gravity	1.2	1.6	1.1
Specific heat	0.92	0.24	0.2

2.3.1 Desiccant Selection

There are varies of solid desiccant available for the specific applications. The preferable characteristics for choosing solid desiccant with particular reference to dehydration of natural gas are, the solid desiccants must have large surface area for high capacity and high mass transfer rate. They must also pose a high bulk density and activity for the components to be removed. They must easily and economically regenerated (Gandhidasan et. al., 2000).

Silica gel used for natural gas drying should be of the Sorbead type because this is the water stable silica gel type. Silica gel thus having a longer lifetime, high adsorption capacity for water low dewpoint, and are not catalytic for sulphur conversion reactions. Silica gel also has a higher capacity for pentane. Their longer lifetime can reduce the operating cost while their high performances enhance the operating safety of natural gas treatment plants compared to others. The problem with silica is its tendency to shatter when contacted with liquid water.

Molecular sieve are crystalline alkali metal alumino silicates comprising three dimensional interconnecting networks of silica and alumina tetrahedral. Because of its uniform structure, molecular sieve will not giving up moisture into the package in case if the temperature rise (Hasan et. al,. 2011) A molecular sieve is the most versatile because it can be manufactured for a specific pore size depending on the application. However, it is more expensive than silica but offers greater dehydration (Saied et. al., 2006).

Alumina is the least expensive adsorbent that is activated by driving off some of water associated with it in its hydrate form by heating. It produces an excellent dew point depression values but require more heat for regeneration. The most efficiency adsorbents are molecular sieves (Dan, 2009).

The final choice of desiccant must be based on the equipment cost, service and applicability to process needs. In most adsorption plant proper design and operation is more critical than choosing the adsorbents (Gandhidasan et. al., 2000).

2.4 Adsorption Unit

In most common configuration, adsorption unit is equipped with at least two beds. Commercially one bed is for adsorption cycle and another one is for regeneration (Michal, 2011).The wet gas flow downward trough the tower in the absorption cycle. Then all the gas is adsorbed at different rates depend on their chemical nature, size of molecules and the size of pores in solid material (Saied et. al., 2006; Gandhidasan et. al., 2000).

2.4.1 Design Consideration

The following considerations are good approximation for estimation of the adsorption dehydration behaviour**.**

- Allowable gas velocity
- Bed length to diameter ratio
- Desiccant capacity
- Breakthrough time

2.4.2 Process Descriptions

Water molecule are adsorbs first in the top layers of desiccant bed and all at once hydrocarbon gasses also being adsorbed. Then, the upper layer of the desiccant bed becomes saturated with water. The lower layer begins to see wet gas and adsorbing is begun. The tower must switch from the adsorption cycle to regeneration cycle before the bed has become completely saturated with water.

For the regeneration, gas flows to trough the adsorbents into a cooler and then further into the separator. Natural gas is flow downwards through adsorption column and regeneration is performed by counter current flow in order to provide complete regeneration from bottom of the column. (Michal, 2011).

Therefore, operational problem that may occur are of poor design, operation and maintenance. Sometimes operators faced problem with the support grid and leakage of molecular sieve. As the result, it is needed to replace the whole bed. Figure 2.1 shows the flow diagram for dehydration by using adsorption methods.

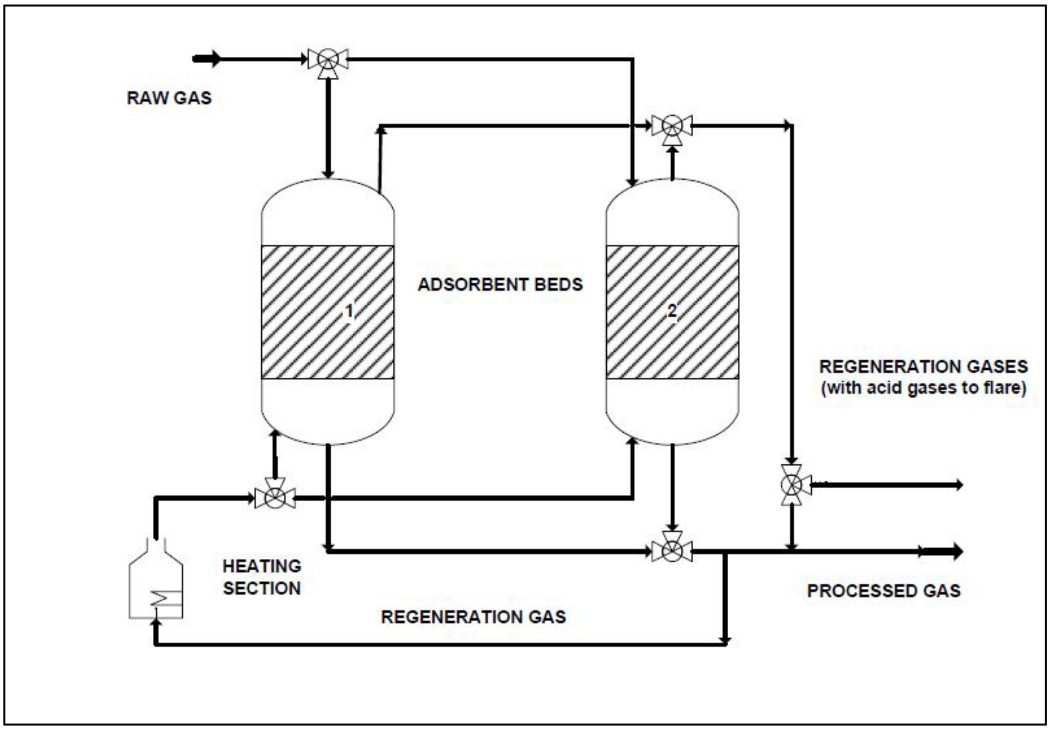

Figure 2.1 Flow diagram adsorption dehydration unit

2.5 Dehydration by Absorption

Absorption is the most common technique where the vapor in the gas stream become absorbed by using liquid desiccant in an absorber (also called contactor) (M.Saied et. al,. 2006). The rich glycol must be regenerated before it can be reuse in the contactor. The regeneration is done by distilling the glycol thus removing the water (L. Dan, 2009).

Although many liquids possess the ability to absorb water from gas the liquid desiccant is most desirable to use for commercial purposes when it possess the following properties : (Muhamadbeigy, 2008)

- Strong affinity for water to minimize the required amount of absorbent
- Low affinity for amount of hydrocarbon to minimize hydrocarbon losses during dehydration
- Low volatility at the absorption temperature to minimize vaporization losses
- Low tendency to form and emulsify to avoid reduction in gas handling capacity and minimize losses during absorption and regeneration
- Good thermal conductivity to prevent decomposition
- Non-corrosive and non-toxic
- Easy and economic regeneration

Inhibitor used in a gas treatment plant can be either an alcohol or one of the glycol types. Determination of amount and concentration of inhibitor and their distribution in different phases are very important for practical purposes and